RESULTS OF SPACE SHUTTLE FLIGHT 51–A

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

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January 30, 1985:

Frederick H. (Rick) Hauck, captain, USN, commander of the 51-A mission; accompanied by David M. Walker, commander, USN, pilot, Mission 51-A; Dr. Joseph P. Allen, mission specialist 1; Dr. Anna L. Fisher, mission specialist 2; and Dale A. Gardner, commander, USN, mission specialist 3 2

RESULTS OF SPACE SHUTTLE FLIGHT 51-A

WEDNESDAY, JANUARY 30, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The committee met, pursuant to call, at 10:10 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

Mr. FUQUA. The committee will be in order. Members and guests will take their seats.

Without objection, permission will be granted for cameras, TV, and recording equipment to operate during the period of this hearing.

We first would like to welcome the new members of our committee that are here. We will have a more formal welcome at a later time when we will introduce you when the committee is officially organized.

But today is a special meeting. We take great pride and pleasure that the committee welcomes the space shuttle crew of Mission 51-A and to congratulate them on a very outstanding performance. This was an 8-day mission that was highlighted by two satellite deployments, and also a very interesting two-satellite retrieval.

Another dramatic first for the mission of this crew was the first attempt to grow organic crystals in the microgravity environment of the orbiter. The 3M Co. scientists will study these crystals produced for their optical properties and other characteristics that might ultimately have made some very important applications in the areas of electronics, imaging, and also in health care.

Commanding the five-member crew was Rick Hauck, commander, and Dave Walker, pilot, and mission specialists Anna Fisher, Dale Gardner, and Joe Allen.

Once again, the space shuttle demonstrated additional flexibility by performing an intricate rendezvous with the disabled satellites and this crew can take great pride in the success of these intricate maneuvers.

At this time I would like to recognize the new ranking minority member of the committee, Mr. Manuel Lujan, and ask him if he wishes to say a few words.

Mr. LUJAN. Thank you, Mr. Chairman. I don't have any questions. I just want to congratulate the crew. We're into a new era, what this space business was all about, and get up there and get them back and fix them down here and send them on back. I just think it was marvelous. We enjoyed watching you all during the

time that you were there, and I'm sure there will be a lot more successes.

Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Lujan.

Commander Hauck, if you would wish to present your report in any fashion, please proceed.

STATEMENTS OF FREDERICK H. (RICK) HAUCK, CAPTAIN, USN, COMMANDER OF THE 51-A MISSION; ACCOMPANIED BY DAVID M. WALKER, COMMANDER, USN, PILOT, MISSION 51-A; DR. JOSEPH P. ALLEN, MISSION SPECIALIST 1; DR. ANNA L. FISHER, MISSION SPECIALIST 2; AND DALE A. GARDNER, COMMANDER, USN, MISSION SPECIALIST 3

Captain HAUCK. Thank you very much, Chairman Fuqua, Mr. Lujan.

I would like to introduce my crew formally to you first, members of the committee. On my right is Dave Walker, who was my copilot, who assisted in the retrieval of the satellites and, in fact, was orchestrator of that effort, as you will see in the movie, a very important task, looking out the back windows, communicating with the ground, and making sure that everything was flowing properly.

On his right is Dr. Anna Fisher. Anna was our chief expert on the use of the Canadian-built remote manipulator arm, the robot arm, and was also my cohort in conducting those maneuvers that the chairman referred to in the rendezvous with the two satellites. She also was in charge of conducting the 3M experiment that the chairman referred to.

On her right is Dale Gardner. Dale is our point man for the conduct of this mission, when 7 months prior to the launch we set about to do it. He did a superb job in that effort, and also as our crewman in charge of launching the Leasat satellite.

On his right is Dr. Joe Allen. He was in charge of ensuring that the launch of our Anik D-2 Telesat communications satellite was conducted properly, and also assisted coequally with Dale out in the payload bay for the retrieval.

With that, we would like to bring down the house lights and show a few slides that will help introduce you to the movie, and then we'll show you the home movies after that.

[Slide 1 shown.]

Captain HAUCK. Every mission has to start with a launch. Unfortunately, ours was 1 day late. We were scheduled for November 7, but due to high-altitude winds that could have damaged the orbiter structure due to the sheer nature, we had to delay 1 day. It was certainly the right decision, and on November 8 we lifted off on our 8-day journey.

[Slide 2 shown.]

Captain HAUCK. One example of a photograph from space of the Earth, this is Typhoon Bill in the vicinity of the Mariannas chain, half way through our mission. In fact, we understand that the typhoon caused such high winds that our communications station in Guam had to be shut down temporarily and, in fact, the Air Force station there was manned under very distressful conditions, but

manned successfully, and continued to give us good communications.

[Slide 3 shown.]

Dr. ALLEN. That was an example of meteorology. Here's one of oceanography. This is looking down at the Straits of Bangka in the Malaysia area. As we look down at the water, oftentimes we can see the glint of the Sun, if the angles are right, and that Sun glint allows us to see features in the ocean that prior to the shuttle flights oceanographers were not really aware of. In this particular example, oceanographers can see the tidal surges coming in from both the north and south ends of the strait, meeting in the middle, and see interactions of those currents and tides that had never been seen before. We would see this in all the oceans around the world. .

Commander WALKER. While most of the Earth is covered with water, the geological features are of considerable interest. We had opportunities to take pictures of a number of those.

[Slide 4 shown.]

Commander WALKER. This is Lake Chad in northern Africa. As you can see, it is largely dry. It once was the size of Lake Erie and has gradually, over the years with the increasing desertification of northern Africa, shrunk down to the very small wetted area that you see now. This is part and parcel of the—in fact, central to—the incredible famine and difficulty that those people have had over there. So this was very interesting to the scientists who are studying that.

[Slide 5 shown.]

Dr. FISHER. This is the 3M experiment which Chairman Fuqua referred to earlier. It was the only experiment that we carried inside the crew module on the middeck. It was an experiment designed to look at crystal growth by diffusion, specifically certain organic crystals. There were six chambers and they were attempting to grow six different types of crystals, or using different solvent mixtures. Three of those are ones which are available to all of us, and three of those were of proprietary interest to the 3M Co.

Basically, they want to look at the growth of crystals in the microgravity environment, using the process of diffusion, and they were very pleased with the results they obtained. They grew experiments that were much larger than anything that they had grown in their ground-based control studies, and they are now in the process of analyzing those for the applications to fiber optics and so forth and are very excited about that and looking forward to flying on future flights on the shuttle.

[Slide 6 shown.]

Dr. FISHER. Now we would like to get into telling you a bit about the EVA portion, so that when we show you the film it will be a little bit clearer to you. We did two rendezvous and EVA's on flight day 5 and flight day 7. This is on flight day 5. At this point Rick and I have done all the maneuvers to bring us in proximity to the satellite, and Joe has flown out with a manned maneuvering unit, or backpack, with a stinger-type device attached to the front of the manned maneuvering unit. The idea is he's going to fly over to the satellite and insert that stinger into the nozzle end of the spacecraft and dock with it, and then using the attitude control feature

on the manned maneuvering unit, use it to stop the rotation. It was rotating at two revolutions per minute at the point that he docked with it.

Then, under a series of commands which we provided from inside the cabin, orienting it such that there is a grapple fixture on the right-hand side of the stinger, and then Rick's job was to maneuver in closer to the satellite, and then I was going to operate the mechanical arm which you see here, and come up and grab the satellite. At this point we're all very excited because everything is going on a nominal plan and it has worked very smoothly up to this point.

[Slide 7 shown.]

Commander WALKER. This is still the nominal plan. As a matter of fact, it's close to the end of it. At this point, you can see that Joe is attached to the upper end of the satellite with the stinger. Anna has grasped the grapple fixture on the stinger with the manipulator arm and has presented it to Dale, who is in a foot restraint there in the bay. Dale is cutting off the omnidirectional antenna which had to be removed so that when we closed the payload bay doors the satellite would fit inside.

After this, the intent was to put the A-frame device, which you see pointed out to Dale's left, on the end of the satellite that Dale is working on, and that would have provided a place for Anna to regrapple it and insert the satellite with an adapter on the other end, on the spacelab pallet, which is sitting in the center of the bay. But, as we soon discovered, due to an obstruction in the antenna area, Dale could not make the A-frame fit. It was a physical impossibility to make it happen, although he tried very hard, and we thought as hard as he could, of different ways to do it. At that point we went to our alternate plan, which involved a considerably different operation to accomplish the same thing, and I'll let you all see in the next slide how that worked.

[Slide 8 shown.]

Dr. ALLEN. This was the start of the alternate plan. Dave was the flight director on orbit for us. We had decided that definitely we had to use a different means of putting the last bit of tooling, the one we call the adapter, on the satellite. And, it began with me putting away the maneuvering unit in its parking place, up near the forward bulkhead, and then getting into a foot restraint that we had brought along just for contingency purposes.

You see it is mounted there on the pallet, and my feet are placed in it. In the plan, which we referred to as plan B, called for Anna, with the arm, to hand the satellite to me. She has just done that and you see I am holding it by the antenna end. Dale is busy working with the stinger which he has removed from the upper end of the satellite, and he is on his way across to the other side of the payload bay to put the stinger away. Next he, while I still hold on to the satellite, will pick up the adapter from its stowage location and fasten it to the upper end of the satellite.

[Slide 9 shown.]

Commander GARDNER. Indeed, that's what we did. Joe, in the position you saw in that former slide, held the satellite for a total of 90 minutes, which as you know is about one revolution around the Earth. For those of you that know Joe, he's a rather short individ-

ual. Now he was 6 foot 4 inches when that whole process started. [Laughter.]

The satellite weighed about 1,200 pounds. He quickly learned that he wanted to get rid of it. And after I had attached the adapter, which was another 500 pounds—so we're close to 1 ton—he handed it off to me, and I held it for a few minutes while Joe went around back to this position, where he could grab hold of this part of the satellite and pull it down into this clamp, and I would pull one of these parts down, and we would manually berth the satellite. The manual berthing was required, of course, because without the aid of that A-frame on top, Anna was not able to use the arm to do the berthing, which is one of the jobs that the robot arm does so well. So we were forced into this situation and, luckily, it all worked out.

The EVA took a total of 6 hours, which incidentally was the time allowed for the nominal EVA also, so we were able to keep within that timeframe. But on the intervening day, between the two space walks, flight day 6, we decided that we would have to replan for the second EVA for the recovery of Westar.

Dr. ALLEN. This shows the results of the replanning. We decided that we would not, on the second attempt, try to use the A-frame to fit across the antenna for fear that if it did not fit, indeed, on this second satellite, the Westar, we would then be in a very difficult position because we could no longer work horizontally in the payload bay.

The reason for that was one-half the volume of the payload bay was now taken up with Palapa. We didn't want to go near Palapa for fear of injuring it, and we certainly didn't want to bang the two satellites together and perhaps badly damage both the satellites in one misguided step. So, we went to a method that, in a sense, replaced the A-frame with me. I did not realize that that had been done until about this point, when it dawned on me that Dale had tricked me into holding the satellite again.

[Slide 10 shown.]

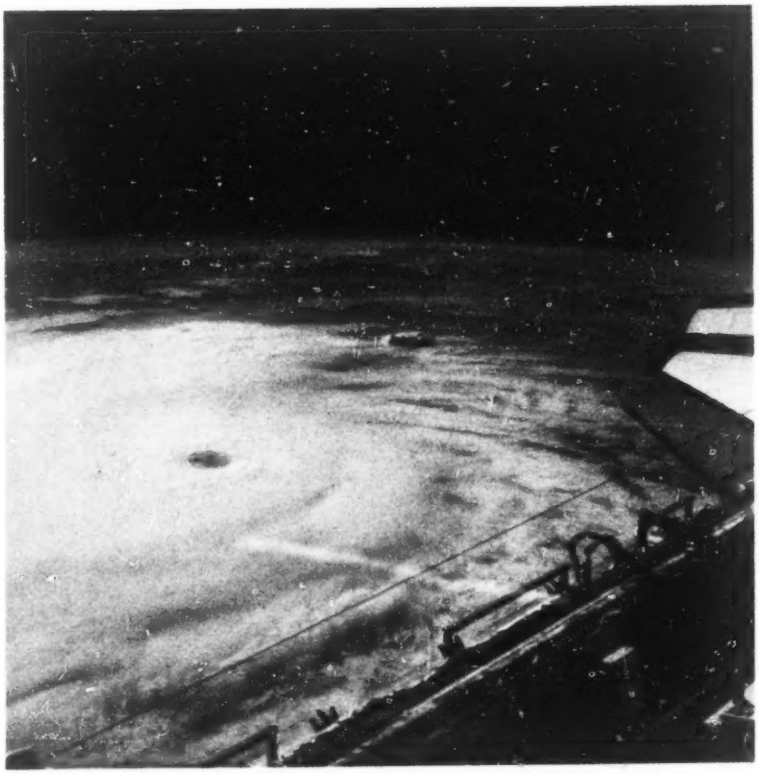
Dr. ALLEN. I'm on the arm. Dale has captured Westar with the maneuvering unit and the stinger, exactly as we had done with Palapa 2 days earlier. He has oriented Westar and stopped it spinning. Rick and Dave have moved the 100-ton orbiter over close to me, to Dale with the satellite, and then Anna has moved me very gently up to the antenna end, and I am reaching out in this photograph and grasping the antenna once again and actually holding the omniantenna, that's like a long pole out the top, under my arm.

I was in many ways relieved to grab hold of the satellite because, as you can see from this picture, one's sense of position is being on the world's highest diving board. [Laughter.]

[Slide 11 shown.]

Captain HAUCK. Well, this is just a picture of the two satellites, once both of them were in the bay, just prior to Anna berthing the arm. It was always comforting for us after this to look back out the rear windows and see those two satellites still in the bay.

SLIDE 1



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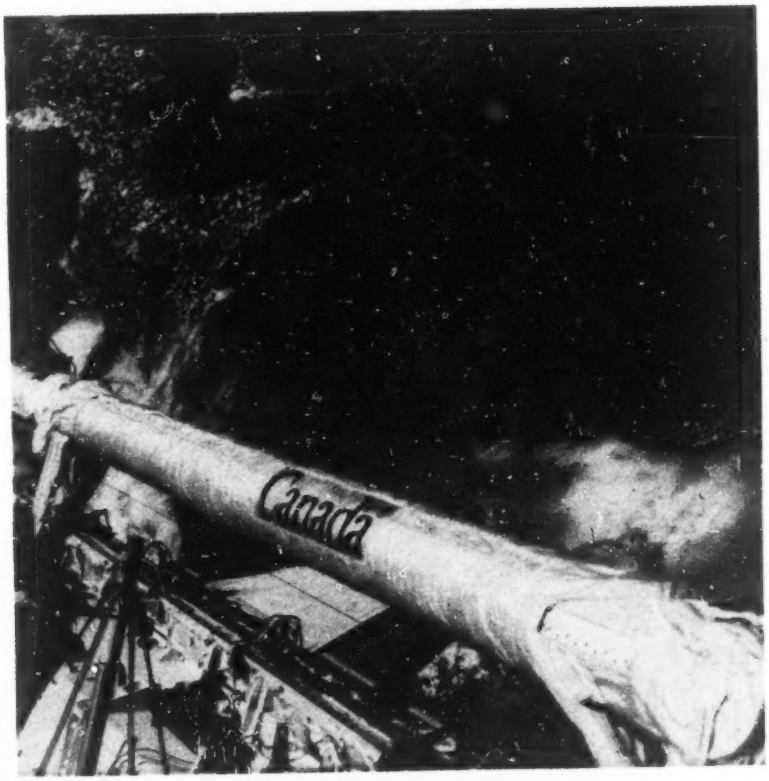

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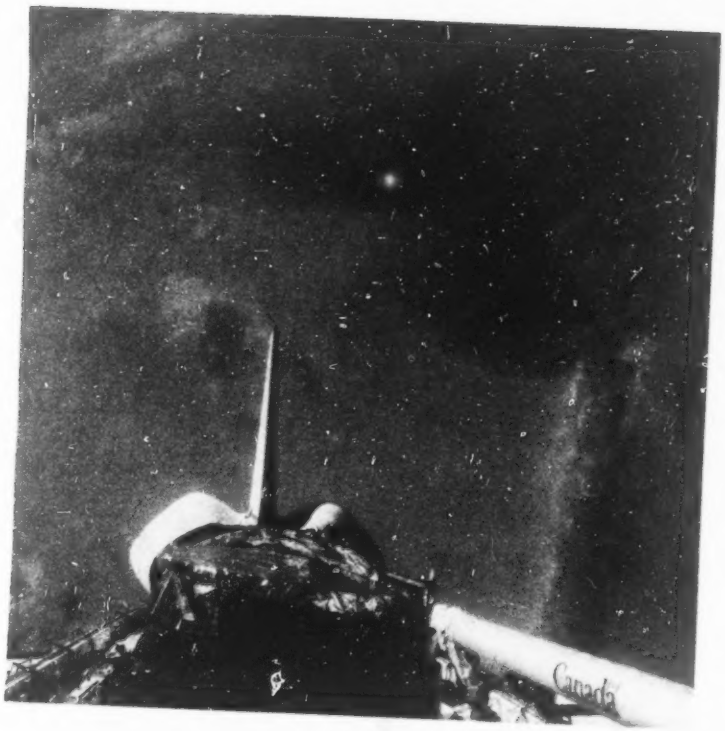

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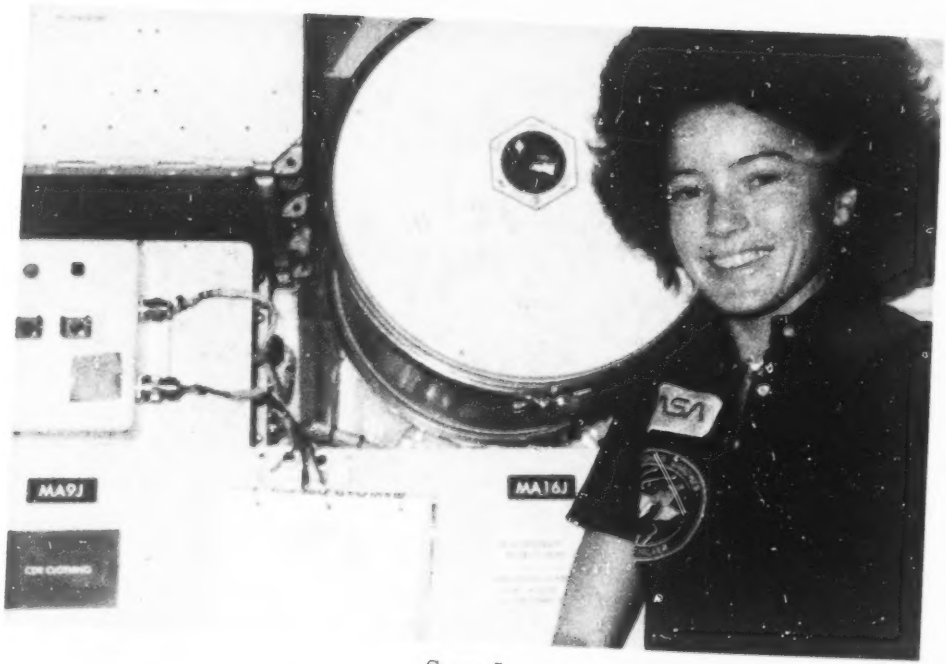
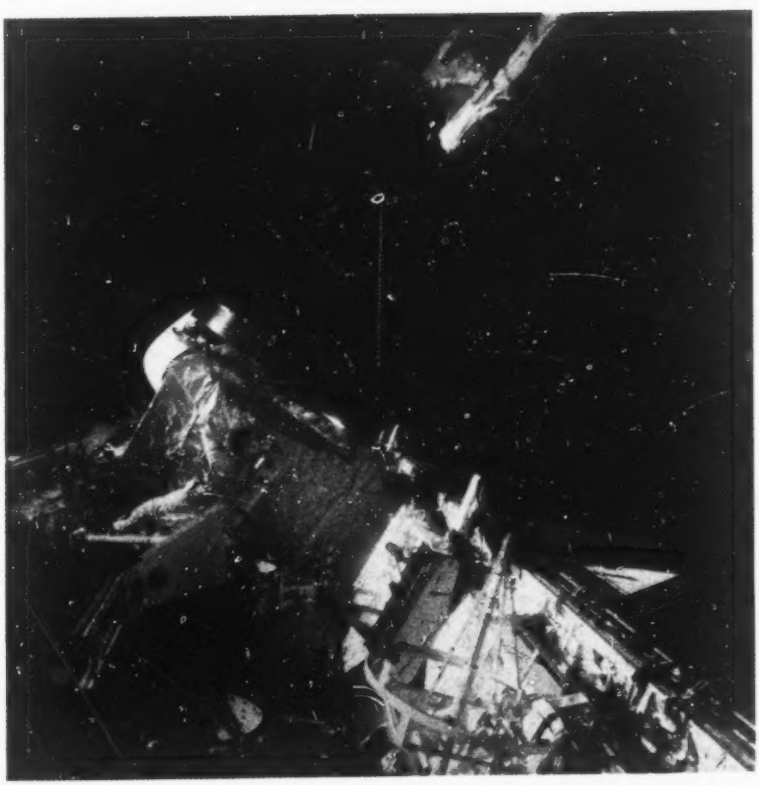


SLIDE 5

SLIDE 6

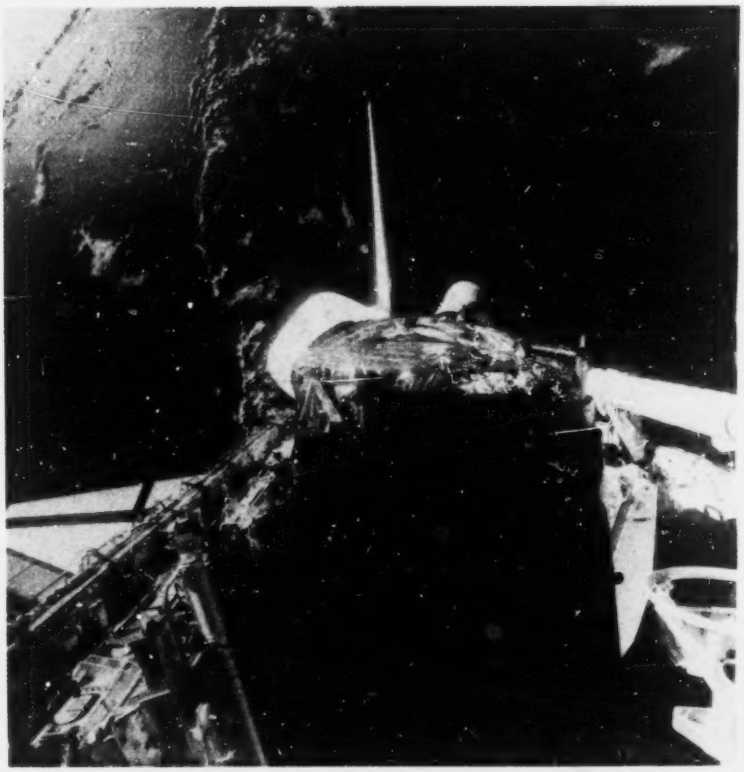


SLIDE 7

SLIDE 8

SLIDE 9

SLIDE 10



SLIDE 11

Captain HAUCK. Well, that is an introduction to the movie. If we will transition now to the movie, I think it will make more sense to you that it might not have without the slides.

[Film presentation.]

Commander WALKER. The movie starts with a closeup of our patch, of which we're very proud, with the American eagle on the front and the two satellites which could either be those we brought up or those we brought down.

Here we see the *Discovery* sitting on the pad the morning of the 8th of November. The liquid fuel main engines just lit, and about 4 seconds after that the sequence starts for the solid rocket motors.

The solids provide 2½ million pounds of thrust apiece, and the main engines provide about half a million apiece, so the total is enough to get you moving fairly substantially. The ride is relatively smooth, some vibration. It feels sort of like an express train going uphill. There's the automatically programmed roll maneuver that gets us pointed east as we leave the cape. The shuttle gradually pitches over to a climb angle of approximately 45 degrees, and the first 2 minutes of the ascent the solid rockets are providing most of the thrust. After the first 2 minutes you'll see the separation motors fire, which will cause the two solid rockets to separate, and the rest of the 8½ minute ascent continues on the main engines alone which, of course, are getting all their fuel from the large external tank.

The ride is considerably smoother once the solid rockets are gone, although the whole thing feels very comfortable and we always felt well prepared. And as you see, we have arrived on orbit.

Dr. FISHER. We launched on Dale's birthday, and we were very pleased when he promised not to blow out those candles. [Laughter.]

This is a view that greets you on orbit, and it is indeed spectacular. On flight day 2, we launched the communications satellite for Canada called Telesat. It's spinning at 40 revolutions per minute as it leaves the bay, and it is the same sort of satellite that we will later rescue on flight days 5 and 7. This was the first nighttime deploy on the shuttle program.

Commander GARDNER. And as Rick mentioned in his opening statement, we also deployed a satellite called a Leasat, owned by Hughes Aircraft and leased to the U.S. Navy. This is the second in a series of four of those satellites. You can see it comes out in that strange frizbee fashion. The satellite was built specifically to be deployed by the shuttle, in that its diameter, as you see, fully utilizes the inside diameter of the payload bay. The satellite is almost then 15 feet in diameter and weighed almost 14,000 pounds at deploy, and we're happy to say that both the Leasat and the Anik satellites are now in their proper geosynchronous orbits and are performing well for the respective customers.

Captain HAUCK. We'll show you a little bit of the flight deck here, just to get you acquainted with it. The upper deck, there are two living spaces, one that we fly the machine from, where the windows are. Now Dave is floating down through an access and you're getting his view of coming down to the lower deck. You can see on the floor some foot loops that are used to stabilize us while

we pull things out of the lockers and so on. You can see our treadmill to the lower right. There's the handle and the tread area. Since you don't use your legs very much on orbit, it's good to use some rubber bungies that hold your legs, hold your body down against it, and you can jog on that for about 15 minutes.

That drawer that's open holds our inflight maintenance kit that we found that we needed to use several times. I think one of NASA's very great strengths is having backup methods to do just about everything. We had a group of astronauts called "Eagle electronics" who fixed several things that went wrong, and we really proceeded per normal.

Here Dale and Dave are pulling some panels off so we can clean some filters on some of the electronic equipment. There is a certain amount of dust that gathers in these filters and to ensure that we have good flow of cool air past the electronics, about every 3 days we would pull those panels off.

Anna here is reaching up with our portable vacuum cleaner. She has her flashlight in her left hand and she's going to stick that wand up through one of the holes where there is another piece of electronics equipment. A clean ship is a happy ship. We are true believers in that. They didn't call me "Captain Bligh" for nothing, I guess. But we really did try very hard to keep the ship clean.

Here Anna and I are preparing lunch. She's putting some water in some of the food containers in the background there, and I'm kind of floating around putting some of the food into food trays that are stuck on the side of the wall there. Eating meals, it was a good time for each of us to get together and just chat about what we were going to do for the next several hours. Ground control in Houston recognized when we were eating and they pretty much left us to our own devices during that time.

When the crew had done good, I brought out a reward. [Laughter.] I think you'll see that at least Anna had done good on that day. Actually, the food in orbit is very good. It's very similar to what we eat here on Earth, and is very nourishing. [Laughter.]

Commander GARDNER. This is the start of the space walk sequence of the film. Here I am in the air lock where we stow the suits. We have three of them, two prime suits and a backup that you see down here. Fortunately, the prime suits worked properly and we didn't need the third suit.

Dr. FISHER. While Dave and Dale and Joe were downstairs getting their suits together, Rick and I were up on the flight deck performing a series of intricate burns that brought us in proximity with the satellites. We were always checking and doublechecking each entry that we entered into the computer and the computer made its own calculations and compared them with those on the ground. We were very pleased when we looked through our optical siting device through the overhead windows and saw the satellite. This is Westar at a distance of 50 nautical miles. It was really something that we were very happy to have had those rendezvous just go as flawlessly, and there was a lot of work put into it by the folks on the ground.

This is then the manual phase where Rick is actually flying the orbiter and putting in inputs to break us and stop our relative velocities toward each other, and it performed very beautifully.

Dr. ALLEN. As you can see, Rick and Anna have moved the 100-ton orbiter up very close to the satellite. It looked to Dale and me as though we could almost reach out and grab it with our hands, although we didn't dare to try that the first time. Instead, we went after the satellite and there you see a bird's eye view of it as seen through one of Anna's cameras on the remote manipulator system.

Under Dave's direction, we went out with the maneuvering unit and the stinger attached to the front of us in order to dock with the spinning satellite and stop it spinning, and then hold it in a very steady way while Anna reached over with the arm to grab us and the satellite.

In this sequence you see Dale flying the maneuvering unit out very gently but very accurately close to the arm. He's coming now across to it. Interestingly enough, the Sun is almost directly behind us as we look out at this scene, and you see the satellite is in shadow. It is in the shadow of the orbiter itself, so Rick is holding the orbiter so that Dale's eyes are shaded and he can, with very good vision, come gently in to dock with the slowly turning Westar.

This is all taking place some 230 miles above the Earth. We're traveling a little over 17,000 miles an hour.

There the EVA crewman—in this case I think it's me—has docked with the satellite, and you notice that the crewman immediately takes up the spin of the satellite, although it's not disorienting in any way, and once we hard dock—that is, we're very firmly docked to the satellite—we engage gyroscopes that we have in the maneuvering unit on command from Dave and Anna there in the middeck—or on the flight deck, rather—as they direct us, and then we stop the spinning of the satellite and can maneuver it around so that Anna can grapple it right on that fixture.

Dr. FISHER. This is the view that you see from that camera under the arm, and it is the means by which I'm able to maneuver the arm and grab the satellite. That system performed flawlessly, as it has in the past.

Commander WALKER. At this point those of us inside are still trying to make sure that we stay ahead of our time line and keep up with the plans, and you can see that on the outside the manual labor is proceeding at a rapid pace. This is the omnidirectional antenna of which we spoke earlier, which has been just removed from the bottom of the Palapa satellite. It's very shortly after that that we discovered things were not going to go as we had originally planned and as they had gone so far.

There you see Dale with the common bracket clamp, which was the piece that was designed to interface with the satellite so that the A-frame could be attached, and you see Joe still attached to the other end of the satellite. Right this second, Dale is beginning to experience a certain amount of frustration because he cannot make that thing fit due to the obstruction that we hadn't planned for.

Commander GARDNER. Then the plan was to get Joe back into the payload bay so he could grab the satellite. To do that, he separated the maneuvering unit from the stinger device, left it on the satellite so that Anna could keep ahold of the satellite with the arm, and then flew back into the bay to doff or get rid of the manned maneuvering unit. There's a place in the bay where we

can stow that unit. In fact, we had two of them. We used different ones for each of the EVA's.

If you watch his hands very carefully, here you can see him making inputs, these little hand controllers that cause the small nitrogen jets to fire to control the unit, and you can see how smooth those flying characteristics are.

If you look in Joe's visor you can see a reflection of the cabin of the orbiter. In fact, here are the windows that the crewmen inside are looking out of. If you look in that one, you can see the camera that's indeed taking these pictures.

Between the windows you see a bright light. Because we're in darkness 45 minutes and daylight 45 minutes, we keep lights on. In fact, you can see Joe even has lights on his helmet, such that as we go into those dark periods those lights provide the illumination we need to continue to work throughout those passes around the Earth and not have to stop during the darkness passes.

In the background you can see I'm getting configured to go on to this plan B that Joe described to you earlier. It was very easy to fly. You see the motions were very easy and very gentle.

Here, of course, Joe has now grabbed the satellite. I have removed that stinger device that he had left on it and have asked Joe now to lift the satellite up out of the way to give me room to translate over and stow the stinger device in preparation for the next phase, which, of course, is going to be attaching that adapter device on to the bottom of the satellite. The adapter was needed because the satellite was never meant to be returned to Earth, so we had to have a piece of hardware that interfaced on one side with the satellite and then on the other side with the payload bay, making a firm connection that we stay rigid during the subsequent entry and return to the Earth. So that adapter obviously was a critical piece of hardware.

And here you can see I have attached it to the spacecraft and am now using a torque wrench to fasten down one of nine latches on each adapter that would form that rigid connection necessary for return.

Dr. ALLEN. As you saw in the slide, I cleverly have handed the nearly 1-ton of mass to Dale, relieved to be rid of it myself for a few moments. But remember, it's zero gravity, so things do not weigh anything at all, and even Anna's locket you see floating in the weightlessness of orbiter around the Earth. Anna is helping direct us, together with Dave.

The effort, we are very pleased to report to you, was a success. We found just by chance this sign floating by at an opportune moment. [Laughter.] And we were able to record this.

Captain HAUCK. This is a view of us passing over Houston at mach 17 at 200,000 feet, leaving an electroluminous trail that a lot of folks on the ground said was the most spectacular sight they had ever seen.

Of course, it's not over until it's over, and that means it's not over until the wheels are on the ground. We deorbited and the weather was good enough for us to come into the Kennedy Space Center in Florida. Of course, it's always good when we can come back there because it means that we can save the time that other-

wise would be spent transporting the orbiter from Edwards Air Force Base or White Sands, NM.

Once again, that's a 300-knot gliding approach, no power. At 200 feet, we have slowed to about 250 knots. Dave puts down the landing gear. This is a long-distance telephoto view as we ease that descent rate from 11,000 feet per minute down to a very gradual couple of feet per second. Here as we pass over the threshold you can see the vapor trailing off the wingtips and you can see the vortices that are produced as the rubber from the tires spins out through that airflow. At about 180 knots the nose is lowered to the ground, and we used about 9,500 feet of the runway. You can bet there were five very happy, very tired folks ready to come back and tell you all about this.

[End of film presentation.]

(Applause.)

Captain HAUCK. Mr. Chairman, if we could, I think each one of us have about 2 minutes worth of what we think this means to the space program.

Mr. FUQUA. We would be delighted to hear from you.

Captain HAUCK. Thank you.

Obviously, this program has gotten routine enough that we can take two satellites into orbit and we think of that as routine. The retrieval mission, of course, receives all the attention. I think that's an indication of the maturity of our delivery system.

The other point I would like to make is that this retrieval effort was pulled together in 7 months. From concept to prosecution, I doubt if there has been another program that NASA has done in such a short period of time as we did this one. It was certainly not a 100-percent-guaranteed effort when we started, but with the efforts of all the people at NASA, Hughes Corp., all the folks that were involved in designing the hardware and training us, it showed what a team effort could do in a very short period of time.

Commander WALKER. The rendezvous and the proximity operations that brought us up to where we could reach the satellites was another team effort. And, of course, it was not done for the first time on this flight, but it was perhaps the most complex series of rendezvous and proximity operations, maneuvers, we have attempted to date.

The fact that we were able to approach within 35 feet of these objects in space, without disturbing them by our presence, without hitting them with our reaction and solar system jets, that I think speaks very well for our ability to do similar things in the future. I think it bodes very well for future space station applications.

Dr. FISHER. Mr. Chairman, I have two points I would like to make. One is in regard to the 3M demos diffuse mixing of organic solutions experiment—that was another project that was developed in a fairly short time period. They were first told that they would fly, or the pot might fly, in February, and so in a very short time they worked very hard to develop their hardware and make sure it was safe enough to fly within the middeck, which has fairly stringent safety requirements.

We are very pleased with those results. This was the first nonaerospace company to fly an experiment on board the shuttle and are very pleased with the results. That, I think, is one of the first

steps toward some of the commercial aspects of space that we look forward to participating with in the future.

The second point I would like to make is that on this flight we used the arm in a slightly different fashion than we had in previous flights. Until this time, whenever we grappled a payload, it was always with a very rigid attach point. We had not used a nonrigid attachment, as Joe Allen might perhaps be described as. But we found that that worked very well, and as long as you use low rates of maneuvering that mass around, so that the momentum didn't develop rates. I think we will perhaps be able to apply those techniques toward building a space station in the future.

Commander GARDNER. Of course, when we launch, we always hope to be able to execute the scenario that we had planned preflight. On our launch day, of course, that was our desire. Looking back on the two space walks in retrospect, however, we realized that we probably learned a lot more given the failure that occurred. Had we not had the failure of that A-frame to fit on the satellites, Joe and I would not have had the opportunity to do the manual handling of the satellites.

In fact, objects of that size and mass had never been handled by human beings in space before. So it gave us an opportunity, although it was a fairly sudden one from our standpoint to experience that, and we learned some important things, we think, one of which is, as you saw when Joe was holding the satellite very close to himself, his face was really filled with satellites, such that although he was able to control it, he had difficulty seeing where the other end, 9½ feet away from him, was going. We learned from that that you need another set of eyes if you have something that big, and those eyes oftentimes were mine or, normally, one of the people in the cabin looking out and telling Joe "the end is starting to wander; move it back to the left or right." That might not be apparent to him, although it was easy to control once he knew where it was going.

The second aspect of it is that you notice that both Joe and I, when we were holding the satellite, had our feet firmly attached to one of those foot restraints and, thus, we were firmly attached to the orbiter. You can imagine what would have happened had we been in our normal floating free state holding on with one hand, of course, and trying to hold the satellite with the other. Every small force or torque that we put on the satellite would not only make it move, but that would react back into our own bodies. We would begin moving, and now the total combination would have been out of control. So it was very important that we became a rigid part of the orbiter such that all the motions we intended to impart on the satellite indeed only occurred on the satellite.

We have passed that information back to the people at Johnson and we hope that will be useful information, both in shuttle flights in the future and also in maybe space station construction.

Dr. ALLEN. Mr. Chairman, about 2 years ago I, together with three fellow crewmen, were privileged to testify before you and the committee about the fact that the space transportation system had become operational. We had, in fact, taken two satellites to orbit and we are proud to be associated with that and report that to you. It seems remarkable to me that here, just 2 years later, we're back

to report that two satellites have been taken to orbit and two recovered from orbit. We were cautioned by our bosses not to get the two confused before going, and we did not get the two confused.

More astounding was the fact that satellites lost in space—that is, they were in the wrong place; we knew exactly where they were, but in the wrong place—arrived at this erroneous position less than 1 year ago today. And so, in the intervening time, we have lost two satellites, we have devised ways to recover them, and we have trained for this mission, we have carried out this mission, and in November of last year we arrived in Florida with the two satellites.

It's an afterthought. We were greeted in Florida, but we were told by people from U.S. Customs interested in the import duty on $60 million worth of satellite. Mr. Chairman, thank goodness you were there to intercede and greeted us. We all felt very proud, together with you, to be part of this special and successful effort.

Mr. FUQUA. Thank you very much. It appears it was not only a great successful mission in the launch of two commercial satellites, which NASA was paid for to do, but also you were paid to recover two satellites, and this is all what the mission was designed to do, plus the scientific experiments such as the crystals that were grown in space.

And from observing the home movies that you made, I think you managed to enjoy all that time, too, together there, which makes it even better. We want to thank you for making the program the success that it is. I think as Joe Allen pointed out, less than about a year ago the two satellites were lost, and I might point out no fault of the crews that launched them.

But someone was telling me the other day that if you didn't understand weightless condition, that when you saw Joe Allen holding up that 1,500-pound satellite, then it helped explain it a little better.

But we want to thank you all for being here today and sharing with us your experience in space.

Do any of our members—Mr. Lujan, do you have any questions?

Mr. LUJAN. One of the things that—you kept talking about damaging one of the satellites with the other when you brought it on to the cargo bay. Did you have a lot of extra room in there, or was it pretty tight to bring them in?

Commander GARDNER. Mr. Lujan, as you saw in the slides and the movie, we had a lot of equipment, hardware, out on the table bay, much of which protruded into the working volume. On the first attempt we were continually cautioned by the people in the cabin that we were getting the satellite too close to some of that hardware. Indeed, it turned out with PALAPA, the first satellite, we did bump it a few times and damaged a couple of the 30,000 solar cells that are on those drums, which turns out not to be that important, but it represented a threat that we didn't want to go any further on.

So the second attempt, we brought the satellite—using Anna with the arm and Joe on the end of the arm—vertically down into the bay, which allowed us a much better working volume and, in fact, the reports we have heard from Hughes say that we did not

damage any of the solar cells. So that was a better plan that turned out.

Mr. FUQUA. Mr. Nelson, do you have any?

Mr. NELSON. Thank you, Mr. Chairman.

I would just ask, from the fantastic result of this mission, what you might share with us that would underscore the need to have the manned presence in the space station.

Captain HAUCK. Mr. Nelson, our experience has been—as a matter of fact, I told one of the underwriters prior to this mission, I said something mechanical is going to fail. We know that. We do the best we can. We build things. We build backups. And in this case our backup was a different plan. In fact, we didn't have a mechanical failure but we had something that didn't fit. Just as on the solar max repair mission, we find that there are things that—when things don't go right, it's a person up there that can make them work out for us. We have saved a $50 million satellite, essentially $60 million worth of hardware there for the insurance underwriters, which by the way, I might add, the underwriters took quite a gamble with letting us do this. They put up some front money, $10 million, that they could have lost.

But with the person in the loop—and I am sure in the space station we'll find that—there are going to be things that will fail, and having someone there to cope with it is just absolutely important.

Mr. FUQUA. Do any of the other members have any questions to ask? Mr. Walker?

Mr. WALKER. Thank you, Mr. Chairman.

First of all, I would like to join with you in congratulating the crew as well. It was a fantastic mission.

The one thing that struck me in watching the film was the use of the torque wrench and some of the kinds of things you had to do. How much physical exertion did you find was needed? I mean, is it something where we found out that you tire very quickly, or can man work for fairly long periods of time with that kind of an effort in weightlessness?

Commander GARDNER. That's a good question. Those of you who remember back to the Gemini Program, when we first did space walks, will recall that individuals went out the first few times with not very ambitious tasks and within 30 minutes were completely exhausted and back inside the cabin. We wondered at that time whether this were possible. Obviously, the learning curve has been a very steep one. Joe and I were out in this instance 6 hours on each EVA, and frankly were not that tired. I'm not saying we wanted to go a lot longer than that. You're starting to reach the end of useful work. But it was not exhausting.

Part of that has been learning how to work in that environment, having handhold properly placed, how to pace yourself and not work too fast, making the tools fit the gloved hand properly, many, many little things that as you might imagine we learned through the years.

The other interesting aspect of the exhaustion that we did not mention during the slides and the movies was that, after each of the EVA's, Joe and I came back into the airlock, into the cabin, having been in these cumbersome suits for 8 hours or so, very excited. And as Dave opened up the airlock to allow us to come back

in the cabin and join them, we expected to see three very excited people, and that was not what we met, unfortunately. It was three very exhausted people. Joe and I both felt that Dave, Anna, and Rick were much more tired at the end of that period than we were. That was the mental exhaustion of their long day. All we had to do was work each individual job out there as it came up. They had to worry about the orbiter itself, flying it, communicating with the ground, keeping us under control, talking to us, all of the myriad of things that go on in this long 15-, 16-hour day. So it really was a five-person effort and that was a good lesson for us to learn in something so complicated as this.

Mr. WALKER. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Gordon.

Mr. GORDON. Mr. Chairman, my name is Bart Gordon. I'm a new Member from Tennessee.

I attended high school with Rhea Seddon-Gibson, who has a mission next month. I hope that I can attend, and if I can't, please tell Rhea hello and wish her good luck. There's a lot of folks in Murfreesboro that I think are going to be coming down.

Mr. FUQUA. I hope you can make it.

Any other members have any questions? Mr. Packard, also a new member of our committee, but a veteran of Congress.

Mr. PACKARD. I am pleased to be on this committee, and certainly congratulate the crew.

I think it is because of budget constraints being perhaps one of the prime agenda items for the Congress this year, it's always nice to know that, as in the trucking industry, that if you can have a full payload going and coming, it's a lot more productive. I hope that in the planning there's a possibility of maybe filling your bays with—going both directions. That certainly is one of the complementary things that we want to give to you on this mission.

Thank you.

Mr. FUQUA. Thank you.

If there's no more questions, we want to thank you and your crew for a very excellent——

Mr. LUJAN. I would like to ask just one question.

Mr. FUQUA. Yes, Mr. Lujan.

Mr. LUJAN. Wasn't that a pretty major goof, that things didn't fit together?

Captain HAUCK. Oh, I wouldn't—I really wouldn't cast it in that light. We have to recognize that those satellites were never meant to be retrieved. As such, those satellites are handmade, individual objects. They're not a production line object. And so when it passed down through the construction details, never expecting to have to recover that satellite again, when some modifications were made, the fact that a little box might have been put an inch here or an inch there really wasn't of concern to them.

I think we have learned a lot. I wouldn't be at all surprised if the underwriters who charge pretty hefty premiums for these satellites might give a little break for those that show that they do give a very good, precise documentation of how their satellites are put together. As we know, documentation itself is expensive, so there might be a tradeoff there. But I can't fault the folks too much by not having the exact documentation.

Mr. FUQUA. Well, thank you again for sharing with us your experiences. We hope to have you back again after you make some other flight. It seems like every flight has a different personality and a different purpose. We were wondering at one time when we would stop having this, but I don't know. It's still very interesting. We keep always being marveled at the interesting developments that occur in each flight. This crew did a first, and I hope it won't be the last.

Captain HAUCK. Thank you, Mr. Chairman. We appreciate your hospitality.

Although I know we don't have time to come up and make a formal presentation, we do have a presentation item, one for you and one for Mr. Lujan. I'll turn it around so that the folks in the back can see, and then turn it toward you.

These are momentos from our flight, a patch and a flag flown on the mission, and a dedication to Chairman Fuqua and Mr. Lujan. We appreciate your support, all of you here on the subcommittee.

Thank you.

Mr. FUQUA. Thank you very much.

The committee will be adjourned.

[Whereupon, at 11:00 a.m., the committee was adjourned.]

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